Diapycnal diffusivity in the core and oxycline of the tropical North Atlantic Oxygen Minimum Zone

M. Köllner[1,2,3*], M. Visbeck[1,2], T. Tanhua[1] and T. Fischer[1]

[1] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, [2] Christian-Albrechts Universität zu Kiel, Germany,
[3] now at BSH Hamburg, Federal Maritime and Hydrographic Agency of Germany, * **manuela.koellner@bsh.de**

SFB 754

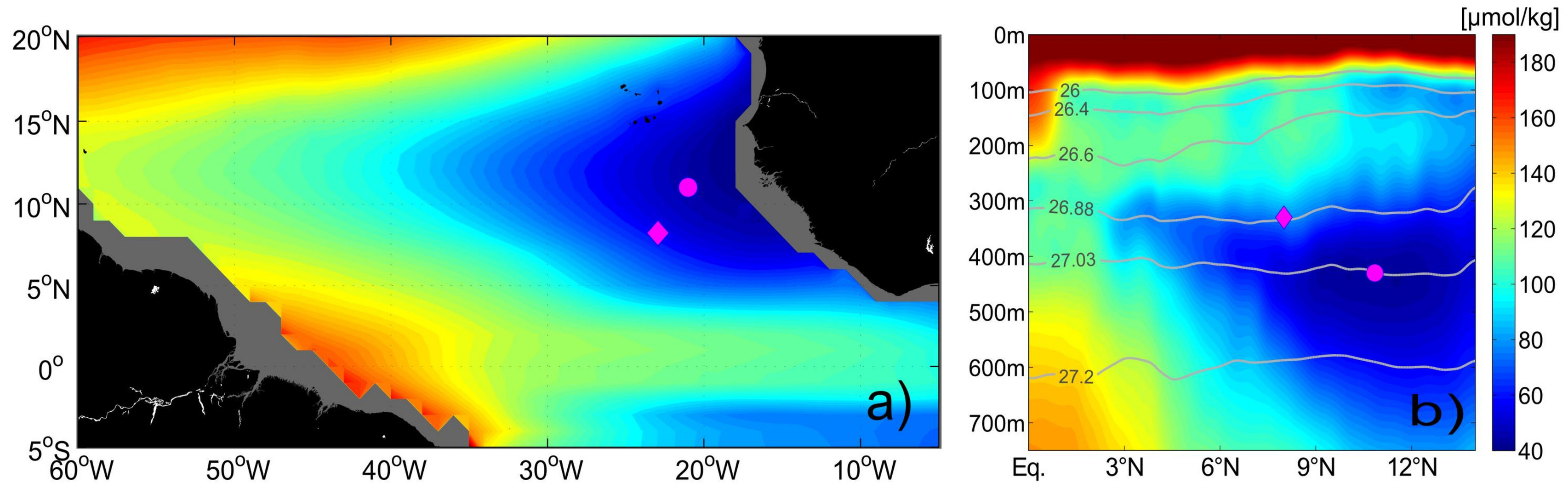
Motivation

Diapycnal diffusivity plays an important role in the ventilation of the Eastern Tropical North Atlantic (ETNA) Oxygen Minimum Zone (OMZ). Studies by Fischer et al. (2013), Banyte et al. (2012) and the synthesis by Brandt et al. (2015) found that diapycnal mixing contributes up to 20%, locally up to 30%, to the oxygen supply in the OMZ.

This comparatively high contribution to the oxygen supply for the ETNA OMZ is the consequence of the weak horizontal circulation within the so-called shadow zone of the subtropical gyre and possibly enhanced mixing over rough topography in the seamount area south of the Guinea Dome (Brandt et al., 2015).

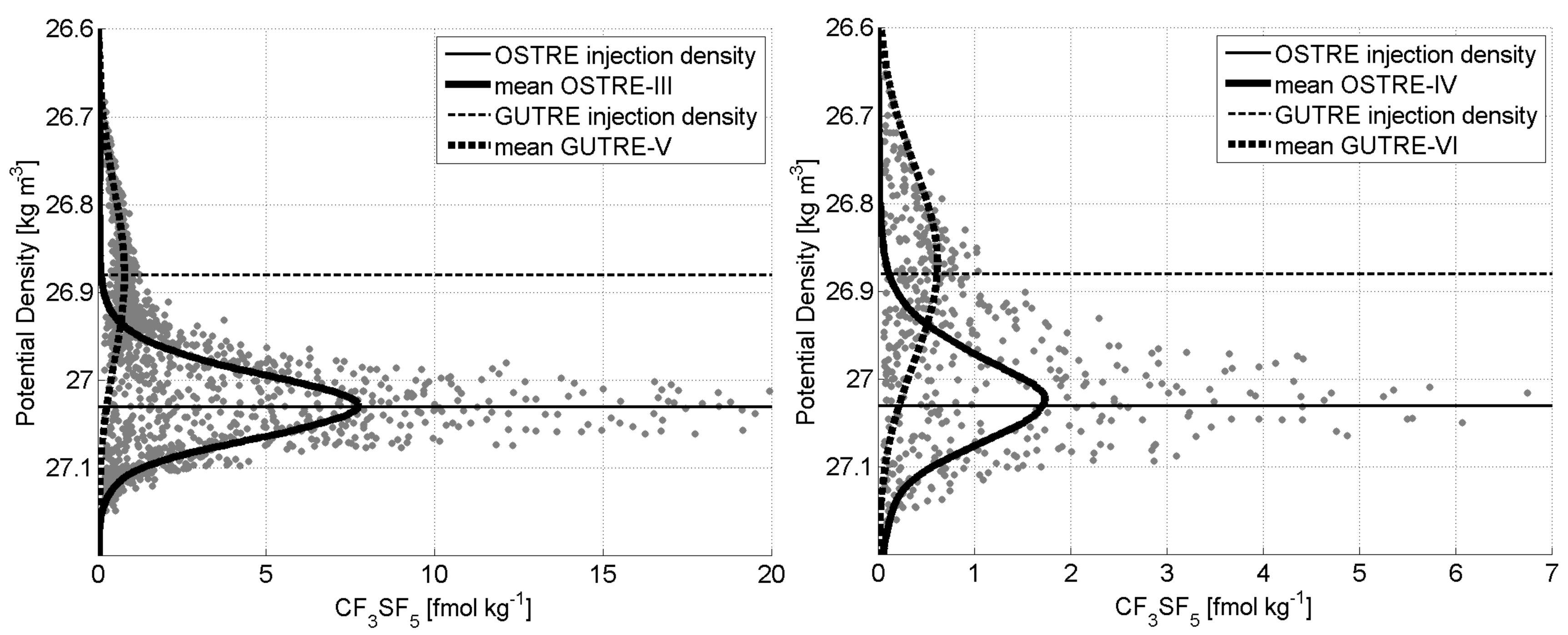
Tracer Release Experiments

For the first time, two Tracer Release Experiments (TREs) within the same area at different depths were realized: the Guinea Upwelling Tracer Release Experiment (GUTRE) initiated in 2008 in the oxycline at 320 m depth, and the Oxygen Supply Tracer Release Experiment (OSTRE) initiated in 2012 in the core of the OMZ at 410 m depth. Repeated measurements of the tracer (CF_3SF_5) allow the quantification of diapycnal and isopycnal dispersion from direct observations.



Oxygen concentration map (a) at 400 m depth in the ETNA OMZ from MIMOC climatology (Sunke Schmidtko, pers. Comm.) and section (b) along 23°W from meridional ship sections (Brandt et al., 2015). Density levels [kg m⁻³] are marked in grey.● injection side OSTRE, ◆ injection side GUTRE.

GUTRE tracer was detected during two of the OSTRE surveys which allowed to estimate diapycnal diffusivity from GUTRE over a time period of seven years.



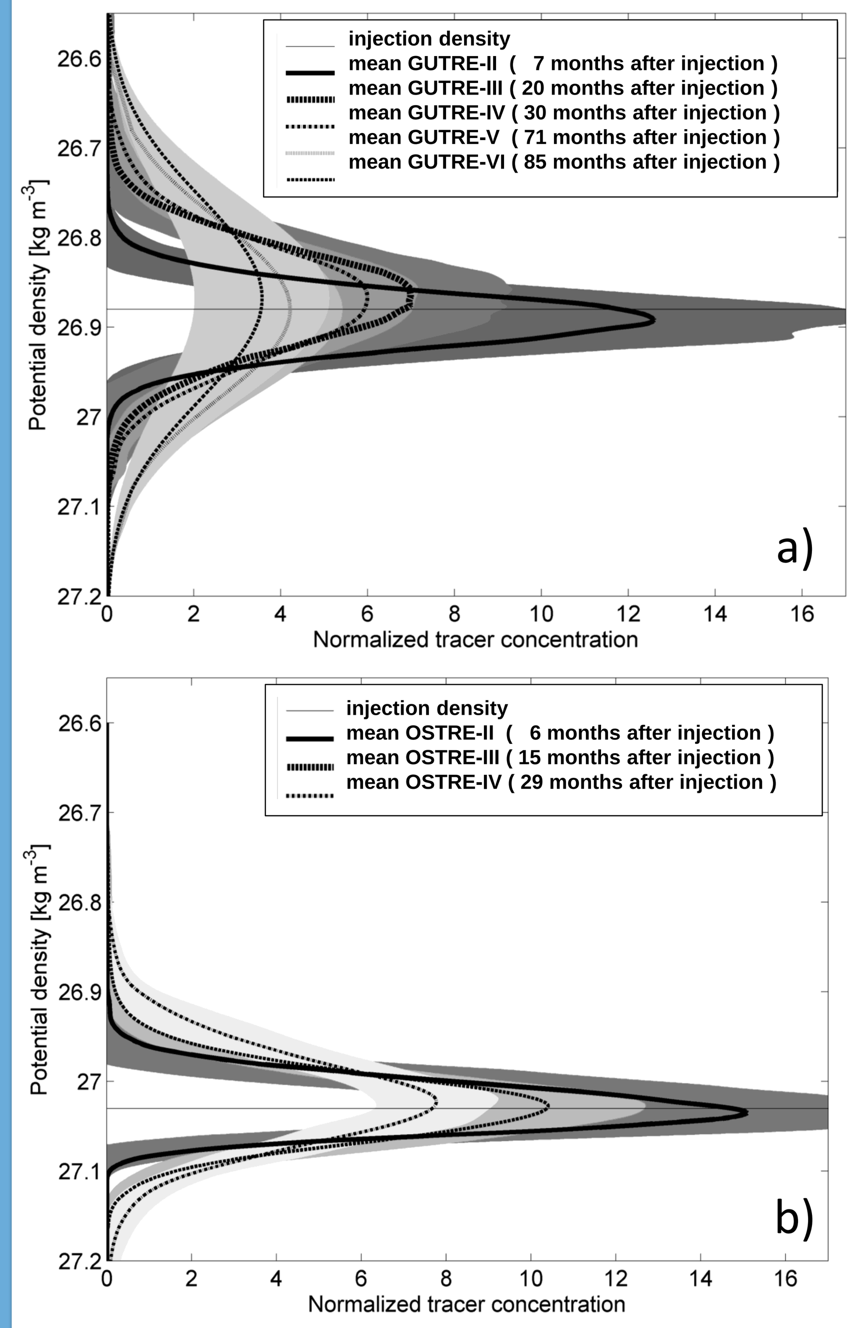
Mean tracer profiles during OSTRE-III 2014 (left) and OSTRE-IV 2015 (right) from raw data (dots) for OSTRE (solid line) and GUTRE (dashed line).

Diapycnal diffusivity

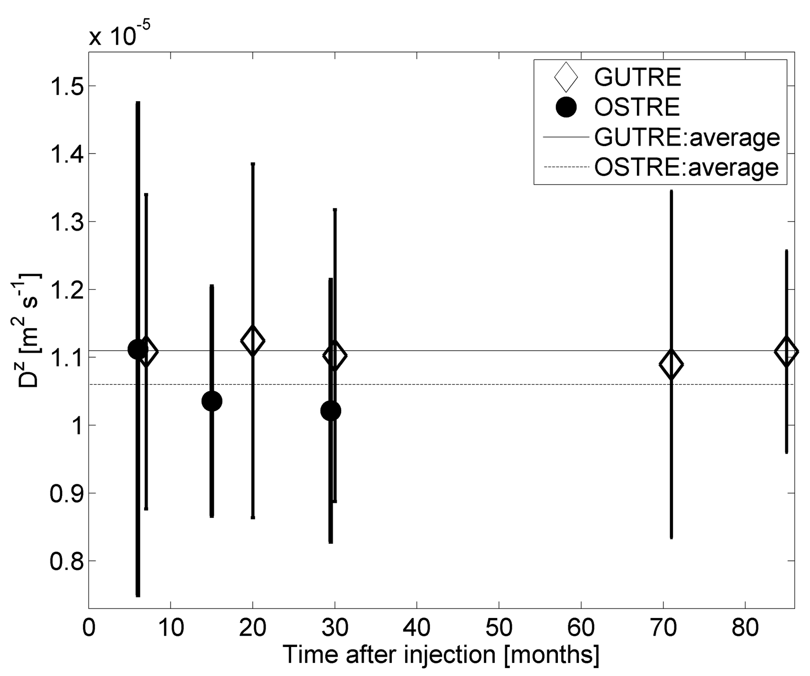
The mean diapycnal diffusivity was found to be $(1.06 \pm 0.24) \times 10^{-5}\ m^2\ s^{-1}$ in the OMZ core during OSTRE.

The result is consistent with the diapycnal diffusivity estimates from GUTRE in the oxycline, as well as with microstructure measurements in the OMZ region. This demonstrate that the diapycnal diffusivity does not vary significantly in the OMZ within the depth range of 200-600 m and does not change in time.

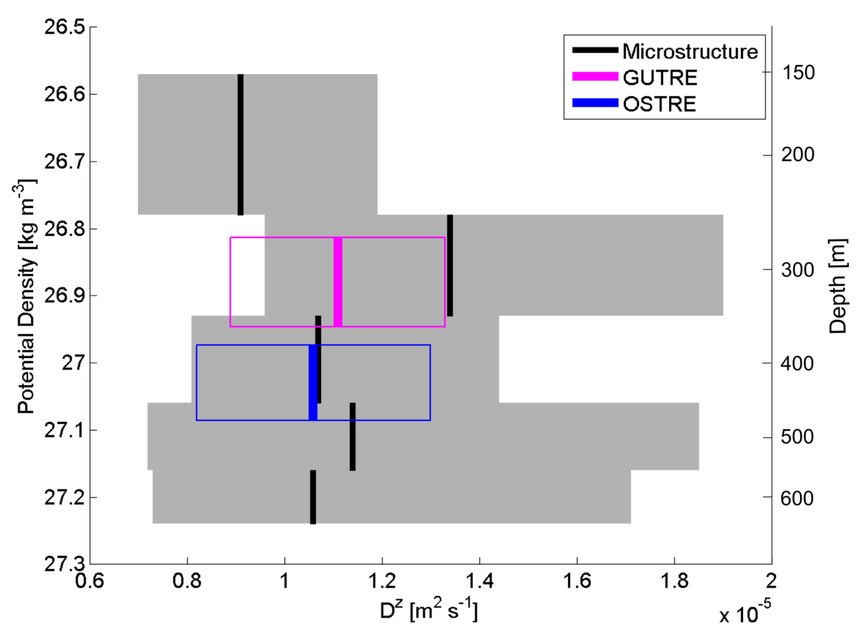
For both experiments no significant vertical displacements of the tracer peak larger than 5 m per year were observed over the entire time period of both TREs.



Normalized mean tracer concentration profiles for GUTRE (a) and OSTRE (b).



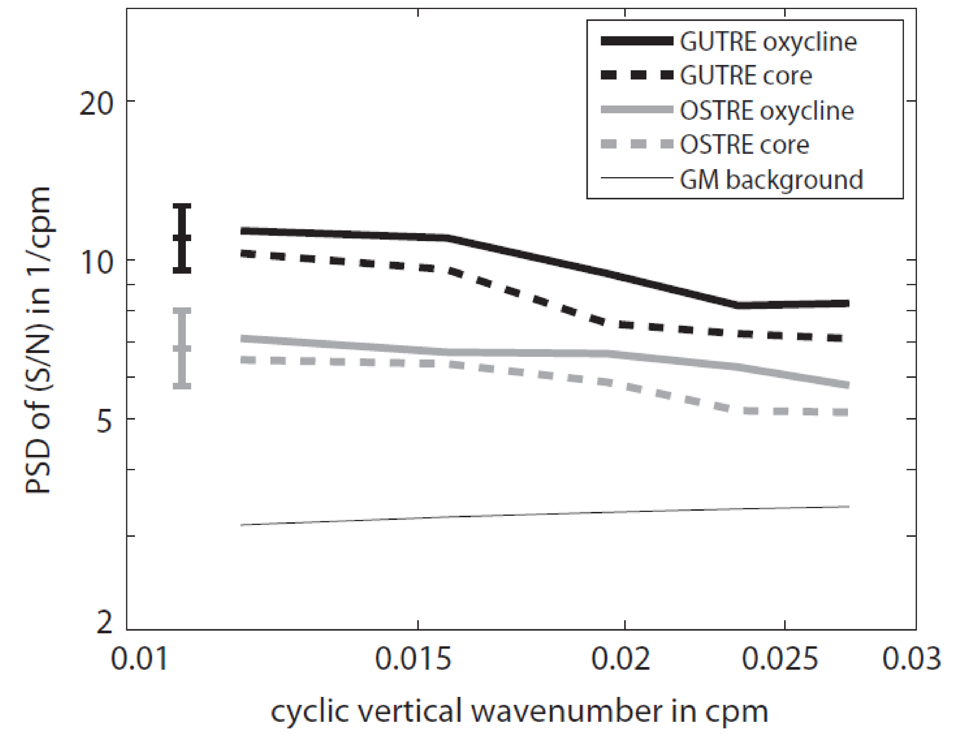
Diapycnal diffusivity coefficients for GUTRE (white diamonds) and OSTRE (black dots). The mean coefficients are marked with horizontal lines.



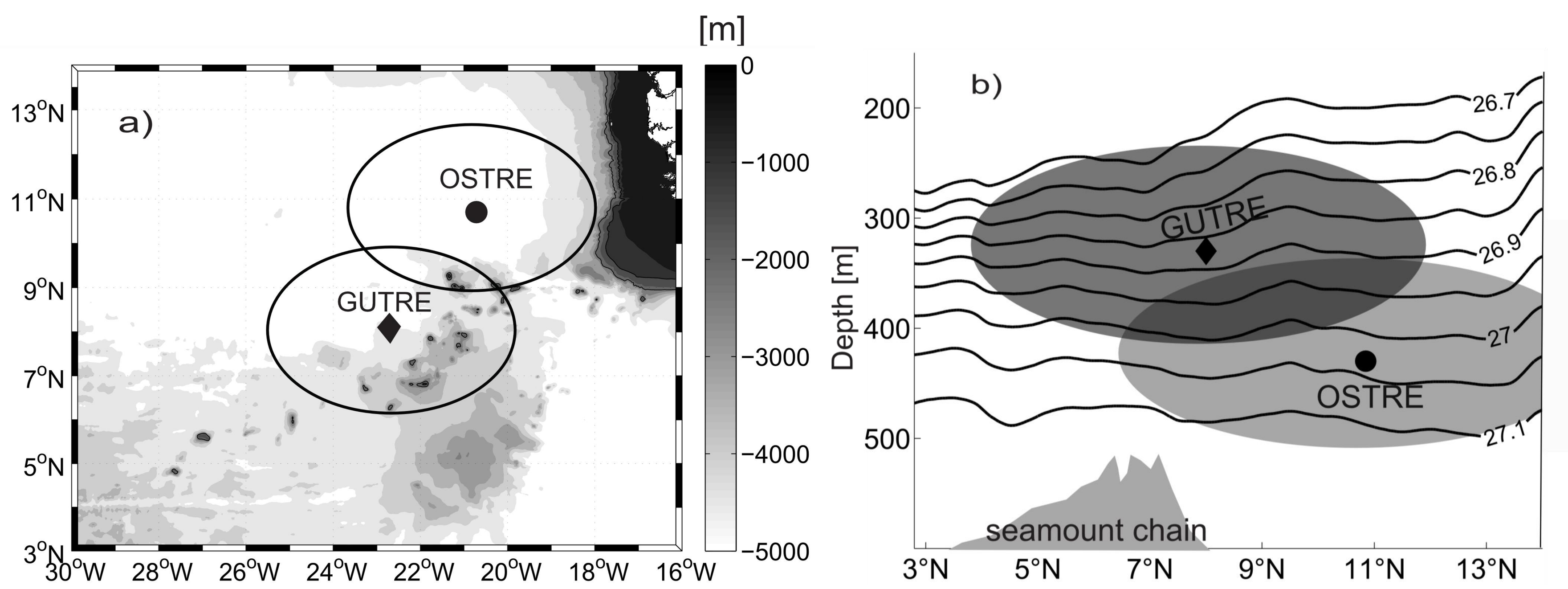
Mean diapycnal diffusivity coefficients for OSTRE (blue), GUTRE (magenta), and estimates from microstructure measurements (black). Boxes are giving the uncertainty ranges.

Enhanced mixing

The diapycnal diffusivity estimates from both TREs are about five times higher than expected from the Garrett and Munk reference (background) internal wave field. Vertical shear spectra from ship ADCP data showed elevated internal wave energy level in the seamount vicinity. Both tracer patches covered increasingly overlapping areas with time and thus spatially integrated increasingly similar fields of local diffusivity, as well as a different local stratification counteracted the influence of roughness on diffusivity.



Power spectral densities of vertical shear, normalized by buoyancy frequency, horizontally averaged over GUTRE (black) and OSTRE (grey) for the oxycline (160-410 m, straight lines) and OMZ core (290-540 m, dashed lines). The thin line shows the spectral level of the Garrett-Munk internal wave field model.



a) Bathymetry in 500 m intervals, the 1000 m and 2000 m isobars are highlighted in black. Ellipses mark the area for which local internal wave fields were calculated with the injection sites in the center.
b) Density layers [kg m⁻³] from meridional ship sections (Brandt et al., 2015) along 23°W.. Ellipses mark the tracer dispersion of both TREs.

- Banyte, D., T. Tanhua, M. Visbeck, D.W. Wallace, J. Karstensen, G. Krahmann, A. Schneider, L. Stramma and M. Dengler, 2012, Diapycnal diffusivity at the upper boundary of the tropical North Atlantic oxygen minimum zone, Journal of Geophysical Research 117, C09016
- Brandt, P., D. Banyte, M. Dengler, S.-H. Didwischus, T. Fischer, R. Greatbatch, J. Hahn, T. Kanzow, J. Karstensen, A. Körtzinger, G. Krahmann, S. Schmidtko, L. Stramma, T. Tanhua, and M. Visbeck (2015). On the role of circulation and mixing in the ventilation of oxygen minimum zones with a focus on the eastern tropical North Atlantic. Biogeosciences 12, 489-512.
- Fischer, T., D. Banyte, P. Brandt, M. Dengler, G. Krahmann, T. Tanhua, M. Visbeck, 2013, Diapycnal oxygen supply to the North Atlantic oxygen minimum zone, Biogeoscience 10, 5079-5093
- Köllner, M., M. Visbeck, T. Tanhua and T. Fischer, 2016, Diapycnal diffusivity in the core and oxycline of the tropical North Atlantic oxygen minimum zone, Jorurnal of Marine Systems, submitted

Deutsche Forschungsgemeinschaft

GEOMAR

Kiel University
Christian-Albrechts-Universität zu Kiel